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ABSTRACT

This study describes the effects of ability-paired student interactions on achievement as fifth graders (ten-year-olds) worked on laboratory activities relating to balance. Achievement gains were assessed (n=83) by analysis of pre/posttest differences on the Lever Concept Test. Audio recordings and field notes (n=30) were analyzed for the following laboratory behaviors: number of words spoken, tinkering, block moving, turns speaking, incidence of helping and distracting behavior. Results revealed that: (1) low-ability student achievement is greater when they are paired with high-ability partners; (2) low-ability students speak more words, exhibit less distracting behavior, and move blocks on the lever less when they are paired with a partner of high-ability; (3) high-ability students speak more words, take more turns speaking, and exhibit more helping behaviors when they are paired with low-ability students rather than with other high-ability students; and (4) there are no achievement differences for high-ability students regardless of the ability level of their partner. These findings suggest that the heterogeneous grouping of students in science can be beneficial to low-ability students partnered with high-ability students, without being detrimental to the high-ability partners. Contains 21 references. (Author)

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THE RELATIONSHIP BETWEEN ABILITY-PAIRED INTERACTIONS AND THE DEVELOPMENT OF FIFTH GRADERS' CONCEPTS OF BALANCE

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The Relationship between Ability-Paired Interactions and the Development of Fifth Graders' Concepts of Balance

Abstract

This study describes the effects of ability-paired student interactions on achievement as fifth graders (ten-year-olds) worked on laboratory activities relating to balance. Achievement gains were assessed (n=83) by analysis of pre/posttest differences on the Lever Concept Test. Audio recordings and field notes (n = 30) were analyzed for the following laboratory behaviors; number of words spoken, tinkering, block moving, turns speaking, incidence of helping and distracting behavior. Results revealed that: (1) low-ability student achievement is greater when they are paired with high-ability partners; (2) low-ability students speak more words, exhibit less distracting behavior, and move blocks on the lever less when they are paired with a partner of high-ability; (3) high-ability students speak more words, take more turns speaking, and exhibit more helping behaviors when they are paired with low-ability students rather than with other high ability students; and (4) there are no achievement differences for high-ability students regardless of the ability level of their partner. These findings suggest that heterogeneous grouping of students in science can be beneficial to low-ability students partnered with high-ability students, without being detrimental to the high-ability partners.

The Relationship between Ability-Paired Interactions and the Development of Fifth Graders' Concepts of Balance

National reform efforts have targeted increased dialogue between students as a critical component of effective instruction. The National Council of Teachers of Mathematics, for example, has called for increased use of problem-solving situations in which students are asked to discuss their ideas, clarify and refine their responses (NCTM, 1989). The recent emphasis on conceptual development in educational research has also led to a renewed interest in the role of verbalization in student cognition. Current popular strategies such as peer tutoring, cooperative learning and Paideia seminars are framed on beliefs that spoken language, social cognition and concept development are interrelated.

Vygotsky (1962) extensively studied the development of language in children and concluded that external verbalization is the initial tool for processing and structuring new information. He suggested that peer interaction is critical for conceptual growth and that cognitive structuring and restructuring occur as children actively exchange ideas. According to Vygotsky, verbal communication contributes to success in achieving basic skills, concepts and knowledge.

Not only is verbalization important for cognitive growth, but Vygotsky also suggested that student verbalization with peers at a slightly higher problem-solving level can maximize their growth in problem-solving. Vygotsky labeled the distance between an individual's problem-solving level and the individual's potential problem solving level with assistance as the "zone of proximal development". Peer

interaction, according to Vygotsky, promotes conceptual development because children can assist one another in the learning process.

One student-student interaction approach that has been shown to increase achievement in a variety of situations is cooperative learning. However, the specific elements of cooperative learning that promote student achievement have not been fully isolated. Many cooperative learning strategies involve a cooperative goal structure, individual accountability, heterogeneous grouping, and face-to-face interactions between students (Slavin,1991). Cooperative learning research typically does not separate these factors, thus the impact of verbal interactions on student achievement is not fully known.

Despite extensive research on the benefits of cooperative learning, some educators have expressed concern about this instructional strategy (Robinson,1990). Advocates of gifted education question the level and rate of achievement of high-ability students when asked to work in groups or pairs with low-ability students (Mills & Darden, 1992). The controversy regarding the use of cooperative learning with gifted students in many ways parallels the concerns that have been raised regarding the elimination of ability-grouped classes (Slavin, 1991). While there is evidence that low-ability students may benefit from heterogeneous student interactions (Slavin & Karweit, 1984), there are mixed reports regarding these placements on higher-ability students (Allen, 1991). There is little research that documents the actual nature of the behaviors and dialogue that occurs when high- and low-ability students work as partners in a classroom setting.

Carter (1992) studied student verbalization and found that the person to whom

a student verbalizes may influence concept attainment. In the present study, we sought to further explore the role that a partner plays in student dyad verbalization and behavior. We examined achievement differences, as well as dyad interactions, as students worked in pairs on two laboratory activities that allowed for exploration of concepts relating to balance. Children's understanding of balance has been explored by a number of researchers (Hardiman, Pollatsek, & Well, 1986; Juraschek & Grady, 1981; Noelting, 1980; Roth, 1991; Siegler, 1976; Tourniere & Pulos, 1985). In this study, balance concepts were used because an understanding of balance involves a complex and multi-level framework that allows students to explore and make conceptual gains at many different levels. The following research questions guided this study:

1) Is there an effect of ability-paired external verbalization on a student's concept attainment?

2) Are there differences in laboratory behaviors for students of different abilities?

3) What is the reciprocal influence of ability-paired grouping on laboratory behaviors?

Method

Subjects

The study was conducted in three urban elementary schools in a large school system in central North Carolina. Three experienced female teachers of grade five science volunteered their classes for participation. Prior to beginning the study, California Achievement Test scores for reading were obtained for each of the nine

participating classes. Each student was assigned to one of three quartile ability groups based on their reading score: high, average or low, paralleling the quartiles achieved by the school system.

Each student was randomly matched with another student into one of five pair types. A HIGH-ability student (those in the upper 25%) could be placed with a low-ability student (lowest 25%), or another high-ability student. A LOW-ability student could be paired with another low-ability student or a high-ability student. AVERAGE-ability (mid-range 50%) students were placed with other average-ability students.

Test Instrument and Classroom Activities

Students were pre- and posttested individually using the Lever Concept test (Carter, 1992). The test was constructed to minimize effects of reading ability. Five questions were verbal and the remaining 12 were pictorial in modality. The questions ranged from simple recall, to applications of varying degrees of difficulty (see Figure 1). This 17 item instrument has a reliability coefficient of 0.73. Validity was previously established by an expert panel.

Pre-post testing and two (55 minute) laboratory periods of lever activities took place over a three week period. The laboratory activities were completed with an assigned student partner and were designed to assist students with formulating concepts about the effect of moving the fulcrum on effort force needed and balancing levers using both equal and unequal weights. During the first lab activity students were provided with a lever, a weight, and a spring scale. Students were directed by

means of a lab sheet to vary the position of the weight in relationship to the fulcrum and measure amount of effort force needed to lift the weight. In part two of this activity, the weight remained stationary but the effort force was measured as it was moved sequentially further from the fulcrum. For activities two and three students were provided with a lever and a set of nine identical blocks. Through a series of trials they were instructed to balance designated numbers of blocks using placements specified on the labsheet.

Procedure

A pilot study involving both qualitative and quantitative measurements was conducted prior to beginning this investigation to establish consistency of method. Minor revisions were made in the timing and implementation of activities.

For each class participating in this study the principal investigators began with a review of the prerequisite concepts and skills using a standardized script. These preliminary concepts included the use of the spring scale to measure force, concepts of force and work, the use of levers in everyday life, and the identification of the fulcrum. Students were instructed to discuss with their partners the lever activities as well as to read instructions to each other aloud as they worked through the two laboratory activities.

A stratified sub-sample of 30 students was randomly selected to be observed by four experienced researchers using predetermined qualitative field techniques. The researchers observed students drawn from the following ability pair types: high-low, high-high and low-low students. Average students were not used in the

focused observations. Each observer made extensive field notes of the verbal and non-verbal behaviors of a single student dyad. Each dyad in the sub-sample was also audiorecorded using a separate audiorecorder and clip-on microphone for each student. During each laboratory session, one of the principal investigators verified that the students not being recorded were conducting the activities as instructed and were verbalizing to their peer partners.

Analysis and Results

Pre- and post test scores were obtained and gain scores in achi ment were calculated. The pretest scores ranged from 1 to 15 correct with a overa mean of 7.58 (SD= 2.6). Posttest scores ranged from 1 to 17 correct. However only one subject scored 17 and the overall mean was 9.90 (SD= 2.8). Next a two-way analysis of variance was used to examine the effects of school and class on achievement. The results of this analysis revealed that there were no significant differences between the different schools or classes within schools.

In order to examine the effects of pairing high- and low-ability students, subsequent analyses involved only those students whose California Achievement Test scores were in the highest and lowest quartiles. Eighty-three students were left in the analyses after excluding average-ability students as well as those for whom necessary data could not be collected (missing pre- or post tests, or parental permission forms.)

The Effect of Ability-Paired External Verbalization on a Student's Concept Attainment

A t-test was used to determine if there was a significant difference in achievement for heterogeneous dyads compared to homogeneous dyads (Table 1). For high-ability

students, there was no significant difference in gain scores whether paired with a high (M=2.57) or a low-ability partner (M=2.64; t=0.14, ns). However, the ability-level of one's partner made a significant difference in concept attainment for low-ability students. Low-ability students who verbalized and completed the laboratory activities with a high-ability partner had significantly higher mean gain scores (M=2.62) than low-ability students placed with a low-ability partner (M=0.77; t= -2.06, p< .05).

This suggests that there is a positive effect on achievement for low-ability students when paired with a student of high-ability. Also, there does not seem to be a detrimental achievement effect on a high-ability student's achievement when paired with a student of low-ability.

Comparison of Laboratory Behaviors of High and Low-Ability Students

The transcripts of audiotapes and field notes from the focused observations of 30 students (from high and low quartiles) enabled us to examine differences in specific laboratory behaviors. The field notes and audiotapes were analyzed across and within different ability pairings of students as described by Erickson (1986). The field notes and transcripts were analyzed and categories of behaviors were identified. As categories were created, responses were compared and contrasted across students (Miles & Huberman, 1984).

Each instance of the following behaviors was coded on the transcript and frequencies were obtained: words spoken, speaking turns, block movement, tinkering, helping behaviors and distracting behaviors. Words spoken included a

count of the total number of words spoken by each individual in the dyad. Words spoken did not include nonverbal behavior. Speaking turns was defined as the number of non-interrupted speaking segments. Block movement included each time a block was lifted up and placed in another area, as well as movement of the spring scale. Tinkering included any manipulation of equipment that was not directed toward answering the questions on the lab sheets. Helping behavior included offering praise, encouragement, advice, waiting for the partner before continuing, explaining, checking for understanding, and sharing equipment. Distracting behaviors included name calling, teasing, not sharing equipment, not waiting for the partner before continuing, not paying attention to the partner, and arguing. An intercoder reliability of 0.84 was determined by an independent coder of a random sample of transcripts.

The frequency of each behavior was obtained and a t-test was used to examine differences in these behaviors for high- and low-ability students (Table 2). High-ability students moved the blocks (M= 26.47) during the lever activities significantly more than low-ability students (M= 16.63). In addition, high-ability students spoke significantly more words (M= 1377) than low-ability students (M=809). However, there was no significant difference in the number of speaking turns for high and low-ability students. There were also no significant differences in the amount of tinkering, helping or distracting behaviors.

Effect of Pairing on Low-Ability Student Laboratory Behavior.

The laboratory behaviors for high- and low-ability students were further analyzed by ability level and the ability level of the student's partner. There were

significant differences in laboratory behaviors for low-ability students paired with other low-ability students, as compared with low-ability students paired with high-ability students (Table 3). Low-ability students paired with other low-ability students had significantly more instances of tinkering, more movement of blocks, as well as more instances of disturbing behavior.

When low-ability students were paired with a high-ability partner, the low-ability students spoke significantly more words (M= 965 words) than those low-ability students paired with another student of low-ability (M= 538 words).

Effect of Pairing on High-Ability Student Laboratory Behavior.

The laboratory behaviors of the high-high ability dyads were compared to the high-low ability dyads (Table 4). High-ability students who were paired with low-ability partners spoke significantly more words, took significantly more turns speaking and exhibited significantly more helping behaviors than high-ability students paired with another high-ability student. There were no significant differences in tinkering, block movement, and disturbing behaviors for high-ability students regardless of whether they had a high or low-ability partner.

Discussion

The finding that low-ability students have greater achievement gains when paired with high-ability students rather than with other low-ability students is consistent with other studies of ability grouping (Slavin,1990). Concerns that high-ability student achievement decreases when these students are grouped with low-ability students were not supported in this study.

When specific student behaviors were examined closely, it was found that high-ability students used more words when conducting activities than did low-ability students. There are several possible interpretations of this finding. Obviously, high-ability students, by definition, have better verbal skills and may be better able to express themselves in discussions with peers. Therefore, they would tend to use more words during the laboratory activities. Low-ability students appear to be less successful expressing themselves verbally and there was evidence that they lacked confidence in their ideas. For these reasons, a low-ability student may be less likely to initiate a verbal on-task exchange with another low-ability student. Additional descriptions of these ability-grouped dyad interactions can be found in Jones and Carter (1993).

Another behavior in which high-ability students differed significantly from low-ability students was in the manipulation of blocks. The fact that high-ability students moved the blocks more frequently may suggest that they had more prior experiences with levers and may have had more successful experiences with experimentation. There was evidence that high-ability students had a greater understanding of the goal of the activities and the importance of moving the blocks to look for patterns in their findings. Low-low ability pairs also showed frequent block movement. An examination of field notes indicated that the low-low ability block moving was qualitatively different. Their block moving behavior was both more random and more rapid. They often failed to make note of their block positions and were therefore unable to make generalizations from their results.

Low-ability students working with other low-ability students exhibited more

tinkering and disturbing behaviors. The trial and error types of strategies that low-ability students tended to employ led to frustration and to subsequent disturbing behavior. Their counterparts, who were paired with high-ability students, exhibited very few disturbing behaviors and spoke nearly twice as many words while conducting the activities. The role of the high-ability student often took the form of motivating the low-ability student to perform by providing guidance in the pattern finding, modeling of thought processes or providing insights (scaffolding) that facilitated concept formation.

High-ability students, when assigned to work in a dyad with a low-ability student, seemed to take on the role of surrogate teacher or peer tutor. The findings that high-ability students spoke significantly more when working with low-ability students, took more turns speaking and exhibited more helping behaviors suggests that the high-ability students were monitoring the progress of their partners.

Advocates of cooperative learning maintain that when high-ability students are placed in group settings with lower ability students, high-ability students gain from having to explain their position and their reasoning. "This not only deepens understanding of the material but also encourages awareness and development of strategies for doing this kind of assignment" (Johnson & Johnson, 1988). Other advantages according to Johnson and Johnson (1991) include better retention of material and the use of higher-level reasoning skills. High-ability students' own concept formation may be strengthened through their verbalization with a lower ability student. However, the data collected in this study do not provide direct evidence of possible benefits to high-ability students from pairing with low-ability

students. Further research is needed to examine these possible effects.

Some educators have questioned the ethics of having high-ability students serve as tutors or models for lower-ability students (Allan, 1991). Robinson (1990) suggests that when teachers tend to "view talented students as ancillary classroom helpers rather than children with individual needs, curiosity, and desires of their own (this view) devalues them" (p. 21). Robinson maintains that when the success of a group of students depends on the ability of a bright student to articulate explanations to other students, this dependency may constitute exploitation of the higher ability student. One recognized disadvantage of heterogeneous grouping to the high-ability student is the reduced pace of learning. However, the use of multi-faceted, complex problems such as those used in the balance activity may mitigate the negative effects of a slightly slower instructional pace.

The data have indicated that pairing a low-ability student with a high-ability student results in achievement gains for the low-ability student. The question that remains to be explored is, "What benefits (if any) are there for the high-ability student?" Further research perhaps through strategies such as concept mapping, may elucidate the differences in concept construction for different student ability dyads.

Implications for Science Educators

The lessons that were developed for teaching balance concepts using levers were based on common accepted practice for good science instruction. Introductory material was given, lab work and the related worksheets that guided exploration were

developed, piloted and extensively field tested. The labs were carefully planned to provide students with the opportunity to explore lever concepts and to gain an understanding of balance based on hands-on experience. Care was taken to use explicit and simple directions, the materials were well organized. In other words, these lessons were developed with much more care than is usually possible under traditional teaching conditions. And yet, despite these very carefully planned lessons, low-ability students working with low-ability students did not gain significantly in knowledge as measured on the Lever Concept Test. Although the transcript revealed that low-ability students seemed motivated to do a good job, they frequently exhibited subtle off-task behavior that was not apparent to the researchers who were teaching and monitoring the students' work. Therefore, it would lead us to believe that these low students have become very adept at hiding their off-task behavior. To the teacher in the science classroom the picture throughout these activities would be one of students learning through hands-on experiences. Only after testing did it become apparent that despite efforts on the part of both instructor and students, without assistance from more advanced peers, low-ability students simply did not demonstrate achievement gains. This finding is certainly one of great concern. If these results continue to be substantiated by other researchers, the implications for educational practice are profound. In terms of costs, efficiency and educational effectiveness it appears that heterogeneous grouping (at least at the dyad level) may be in the best interest of our students.

The results of this study support the recent movement away from homogeneous grouping in science classes and toward heterogeneous grouping strategies such as

cooperative learning. The verbal interaction that took place during the two laboratories supported concept development for dyads of unequal abilities. The joint manipulation of the blocks accompanied by discussion of ideas by the high-low ability paired students led to greater gains in achievement than those achieved by the low-low ability paired students. These findings support the formation of science groups and laboratory dyads composed of heterogeneous students.

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Table 1

Gain Scores By Ability Level and Pair Type

QUARTILE	Mean	SD	N	t
LOW				
partner				
low				
(L-L)	0.77	1.79	13	
high				-2.06*
(H-L)	2.62	3.36	14	
HIGH				
partner				
low	2.64	2.65	16	
(H-L)				0.140
high	2.58	2.77	40	
(H-H)				

p<0.05*

Table 2

Laboratory Behaviors By Student Ability Level

	High (N=19)		Low (N=11)		
Behaviors	Mean	SD	Mean	SD	t
Tinkering	4.00	2.65	5.27	5.51	0.710
Blocks	26.47	12.18	16.63	12.30	-2.12*
Words	1367.68	61.80	809.36	317.66	-3.32*
Turns	18.21	59.67	143.00	58.23	-1.670
Helping	16.26	7.20	13.91	8.97	-0.740
Disturbing	2.42	4.75	1.81	2.78	-0.440

$p<0.05$*

Table 3

Laboratory Behaviors of Low-Ability Students By Partner Ability Level

	LOW - low (N=4)		LOW - high (N=7)		
Behaviors	Mean	SD	Mean	SD	t
Tinkering	11.00	5.10	2.00	1.83	4.35*
Blocks	27.25	7.27	10.57	10.37	2.81*
Words	537.50	222.18	964.71	257.04	-2.77*
Turns	108.25	63.65	162.86	48.59	-1.610
Helping	12.50	5.26	14.71	10.87	0.140
Disturbing	4.50	3.11	0.29	0.76	3.54*

$p<0.05$*

Table 4

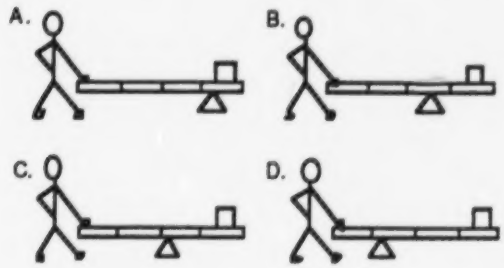
Laboratory Behaviors of High-Ability Students by Partner Ability Level

	HIGH - low (N=8)		HIGH - high (N=11)		
Behaviors	Mean	SD	Mean	SD	t
Tinkering	4.88	2.53	3.36	2.66	1.250
Blocks	21.88	12.98	29.81	10.96	0.180
Words	1789.88	619.23	1076.18	424.79	2.99*
Turns	212.13	60.00	157.00	50.01	2.18*
Helping	20.38	7.30	13.28	5.81	2.37*
Disturbing	3.75	7.07	1.45	1.81	1.040

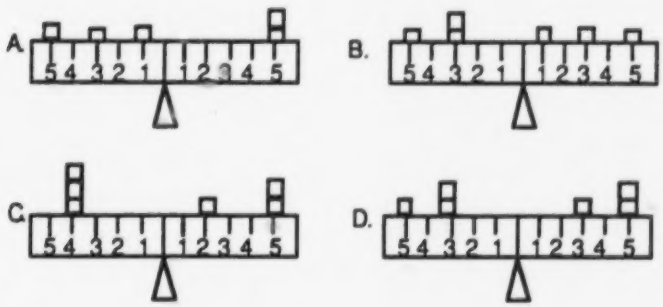
$p < 0.05$*

___1. A spring scale is used to measure
A. work
B. force
C. energy
D. distance

___2. Where would you place the fulcrum to make lifting the block easier for the person?



___3. Which seesaw is balanced?



___4. Which seesaw is balanced ?

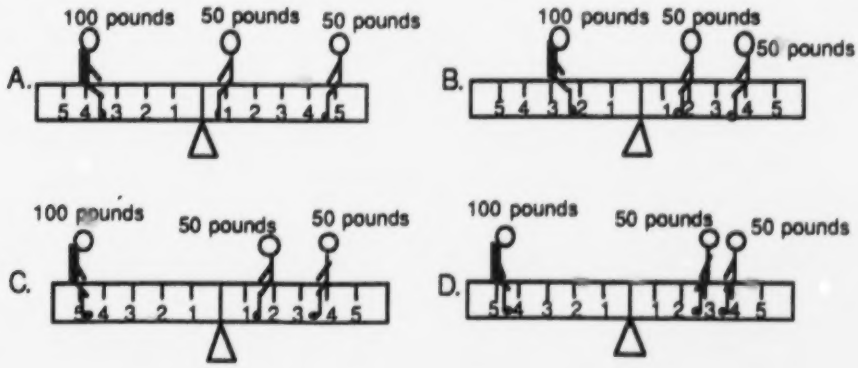


Figure 1. Sample items from the Lever Concept Test.